

Zinc-nickel Plating for Propellant Actuated Devices (PADs)

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Development Branch

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Background

- Corrosion protection is critical to long term ejection seat reliability and operation
- Cadmium plating is used extensively in Propellant Actuated Devices (PAD) items

Pros ✓

- Good corrosion protection
- Thin enough for threads
- Good lubricity

Cons !

- Cadmium plater pool is drying up
- EPA regulates cadmium in air
- Cadmium toxic, carcinogen

Objectives

- Find a non-proprietary replacement, low toxicity, plating that provides corrosion protection \geq existing cadmium plating.
- Evaluate our low VOC painting system on the replacement coating.
- Assure that cadmium replacement doesn't induce hydrogen embrittlement.
- Qualify the replacement system.

Cadmium Replacement Selection

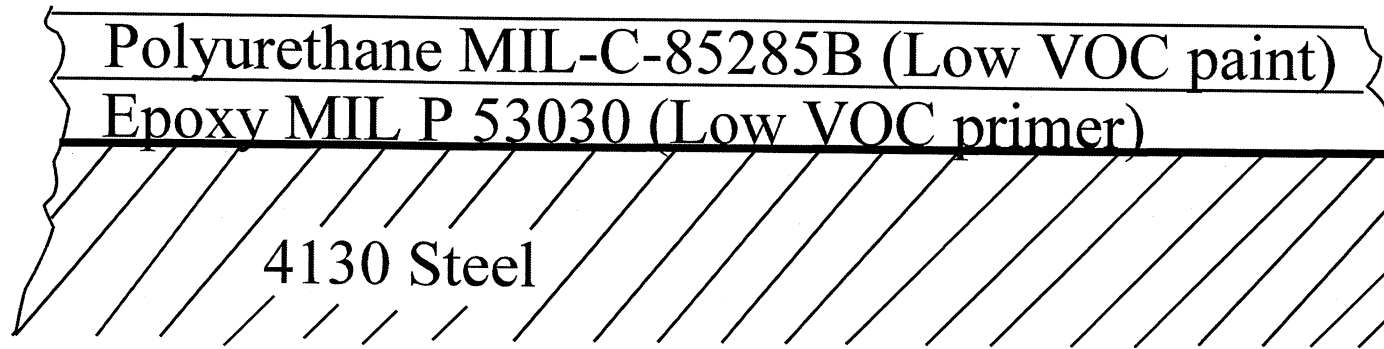
- Zn-Ni got favorable reviews in our extensive literature search
- Japanese automakers use Zn-Ni as a cadmium replacement
- Zn-Ni is *not* a proprietary coating

Overview

- Test results
- Process development
- Example components
- On-going work
- Lessons learned

1st Phase Test Panels: Cadmium

Previously Tested



Control Painted

Control Unpainted

Hex-Chromate Conversion
Cadmium Plate

Low VOC paint
Low VOC primer
Hex-Chromate Conversion
Cadmium Plate

4130/ 4340 Steel

4130 Steel

1st Phase Test Panels: Zinc-Nickel

Threaded

Teflon® water based gel

Zinc-High Nickel

Nickel Strike

4130/ 4340 Steel

Naval / Shipboard

Air Force / Internal

Hex-Chromate Conversion

Zinc-High Nickel

Nickel Strike

4130/ 4340 Steel

Low VOC paint

Low VOC primer

Phosphate Conversion

Zinc-Low Nickel

Nickel Strike

4130 Steel



INDIAN HEAD

Surface Warfare Center Division

Test Matrix



INDIAN HEAD

Surface Warfare Center Division

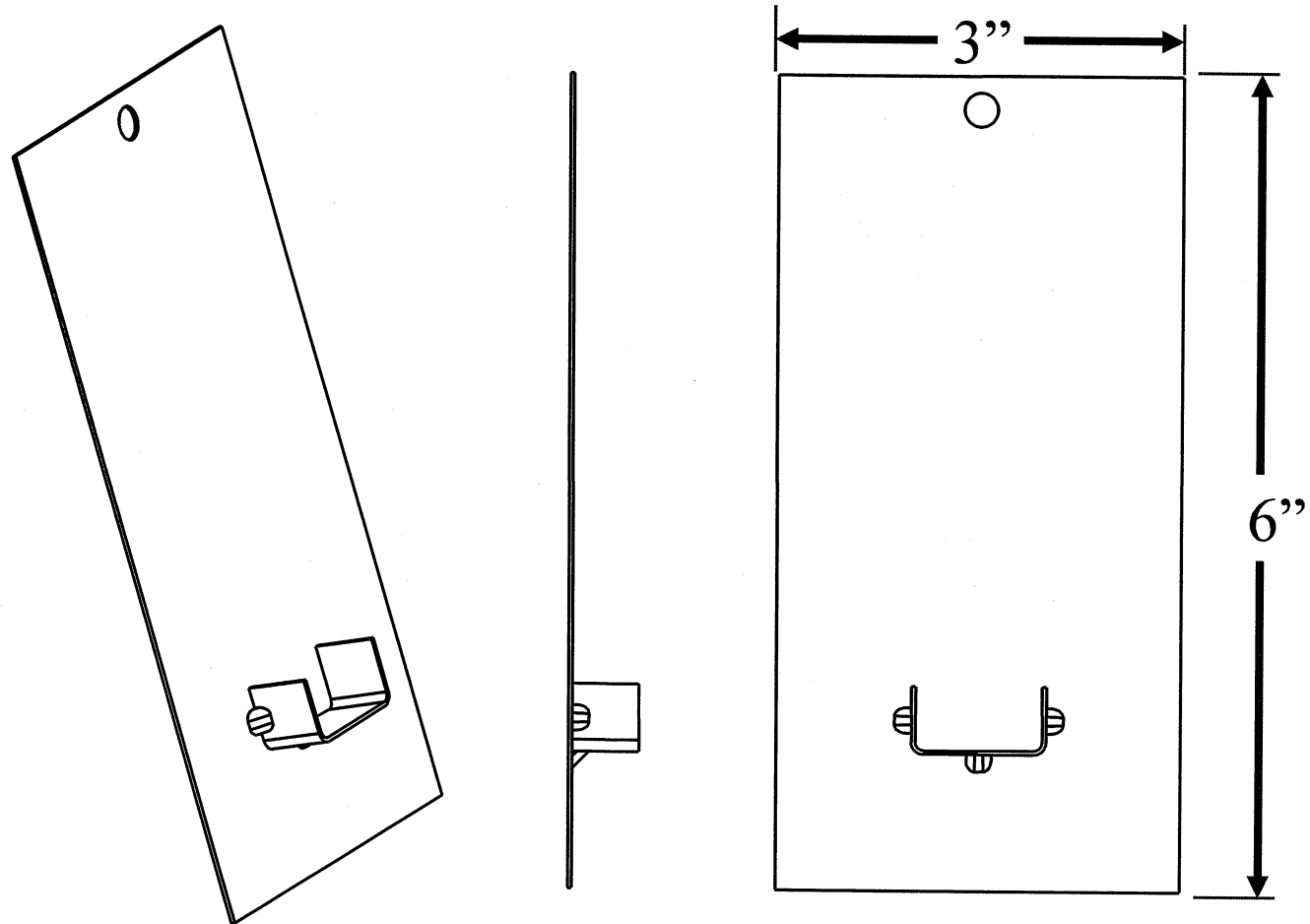
Cadmium Replacement Test panel Test Matrix Overview.

Tests		Control			Zinc - Nickel		
		Bare Metal	Cadmium Plated	Cadmium Plated Painted	Unpainted PADS		Painted
					Chromate Conversion	Teflon Coated	
Each number represents (3) Test Panels							
a	Working Properties			3			6
b	Surface Appearance			Same above ↑↑			Same above↑↑
c	Coating Anchorage			Same above↑↑			Same above↑↑
d	Adhesion dry tape		2	3	4	5	6
e	Adhesion Wet Tape			3			6
f	Water Immersion			3			6
g	Temperature Cycling		2	3	4	5	6
h	Rain Test	1,1	2,2	3,3	4,4	5,5	6,6
i	Humidity Test	Same above↑↑	Same above↑↑	Same above↑↑	Same above↑↑	Same above↑↑	Same above↑↑
j	Salt Fog	Same↑↑	same↑↑	same↑↑	same↑↑	same↑↑	same↑↑
k	Chip Resistance		2	3,3	4	5	6,6
l	Bend Test			3			6
0.39" x 3.94" x 0.035" 4340 Steel Strip Configuration Three test strips per Test Type							
m	Hydrogen Embrittle-ment	7	8		9	10	11 Not Painted

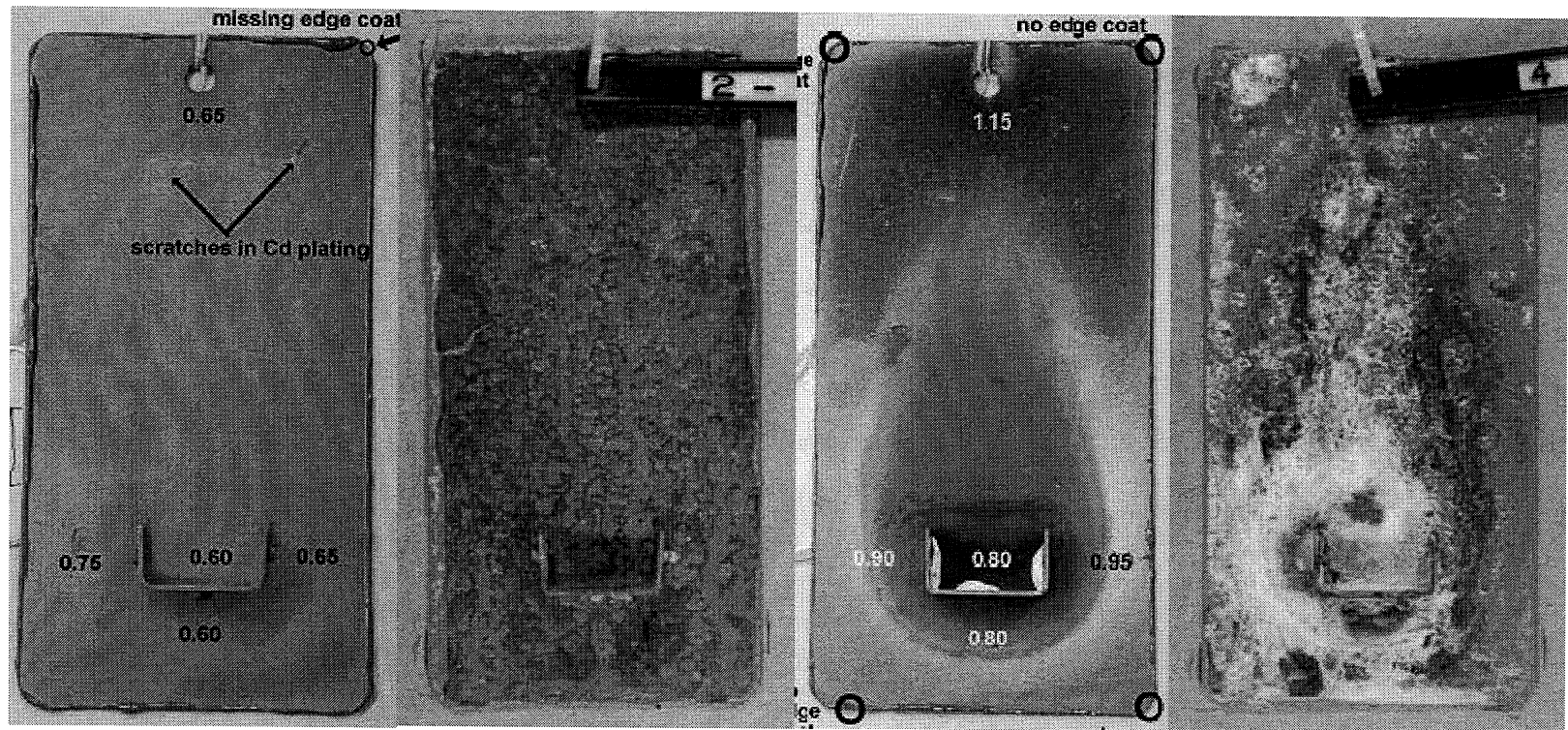
Test Matrix Legend

- a MIL-PRF-81352B Section 3.6
- b MIL-PRF-81352B Section 4.5.2
- c FED-STD-141C, Method 6304.1
- d ASTM D3359
- e FED-STD-141C, Method 6301.2
- f FED-STD-141C, Method 6011
- g MIL-P-83126A, Section 4.4.2.13
- h MIL-P-83126A, Section 4.4.2.14.1
- i ASTM D2247-99, and MIL-P-83126A, Section 4.4.2.14.2
- j ASTM G85 ANNEX 5
- k ASTM D3170
- l ASTM D522 or ASTM D4145
- m Use Dipsol Gumm Ventures test for BS EN 2831: 1993

1st Phase Test Panels: Environmental 4130 Steel



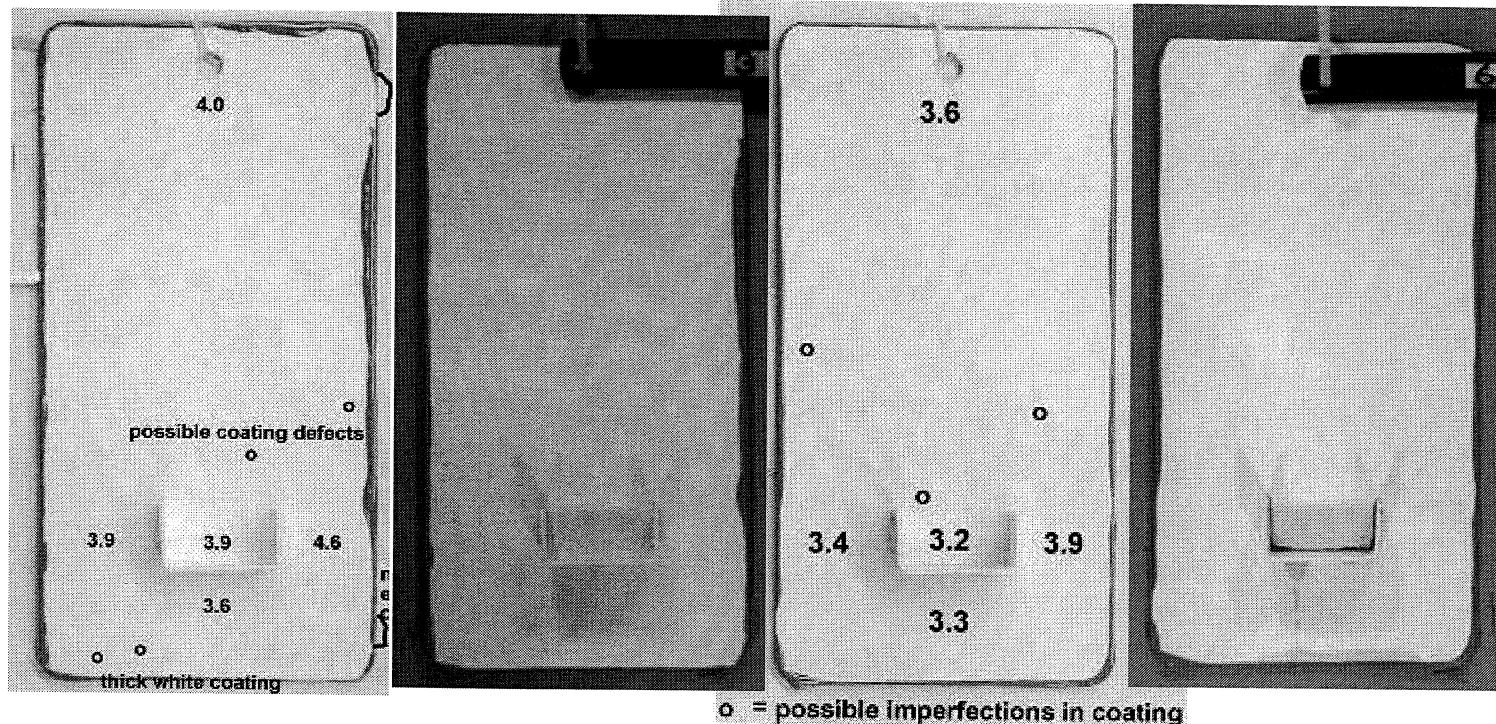
Results: 120 Day Salt Fog Test



**Cadmium Plated per
MIL-STD-870, Type II,
Class 1**

**Zinc - 9% to 13%
Nickel Plated per
ASTM B841-94, Class 1**

Results: 120 Day Salt Fog Test



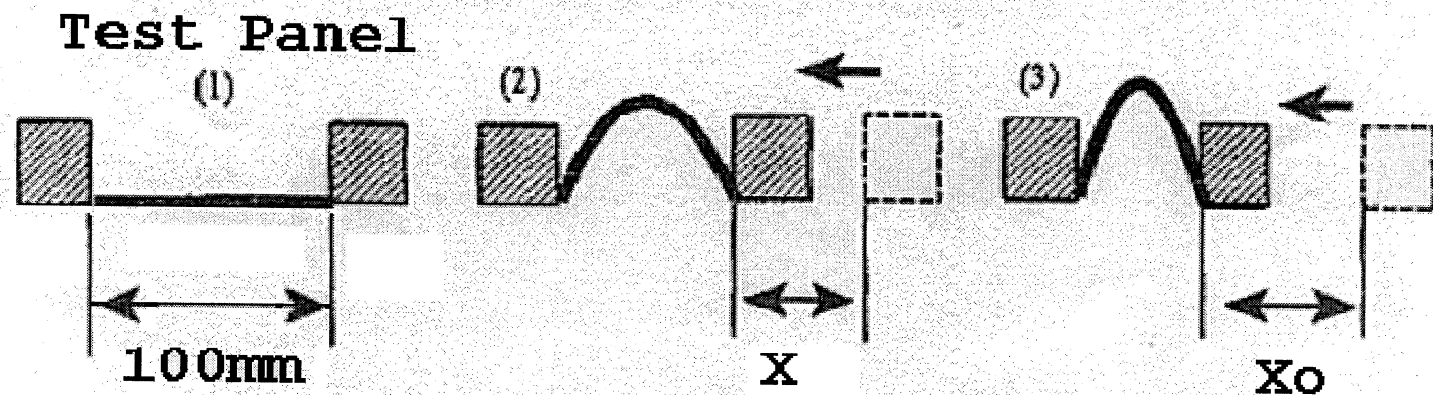
**Cadmium Plated:
MIL-STD-870,
Type II, Class 1,**

**Zinc - 5% to 7% Nickel per
ASTM B841-94, Class 1\ Zinc
Phosphate Conversion Coat**

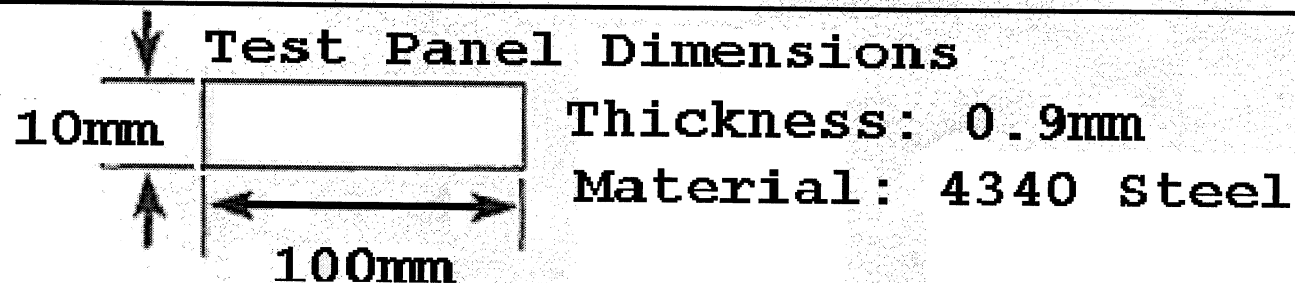
Standard Prime and Paint After Plating

DIPSOL-GUMM Ventures

Hydrogen Embrittlement Testing



$$\text{Hydrogen Embrittlement (\%)} = 100 * (X_o - X) / X_o$$



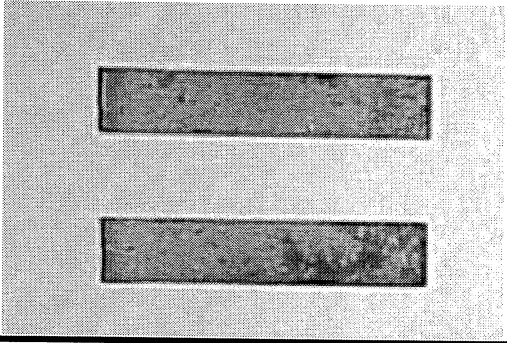
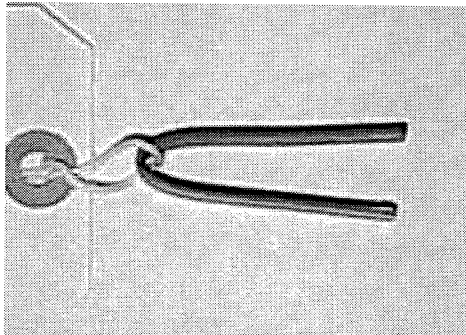
X_o: Standard unplated panel movement before break

X: Plated panel movement before break

2nd Phase Hydrogen Embrittlement Test Specimens

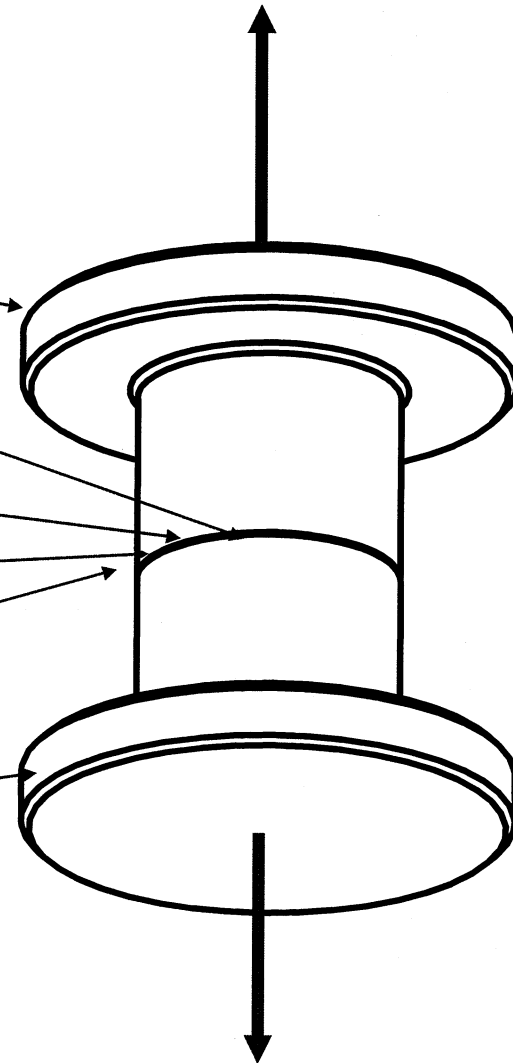
- 1st Phase no stress relief after machining and heat treating
- 2nd Phase stress relieved per ASTM B 849-94 after heat treating

Hydrogen Embrittlement % Results

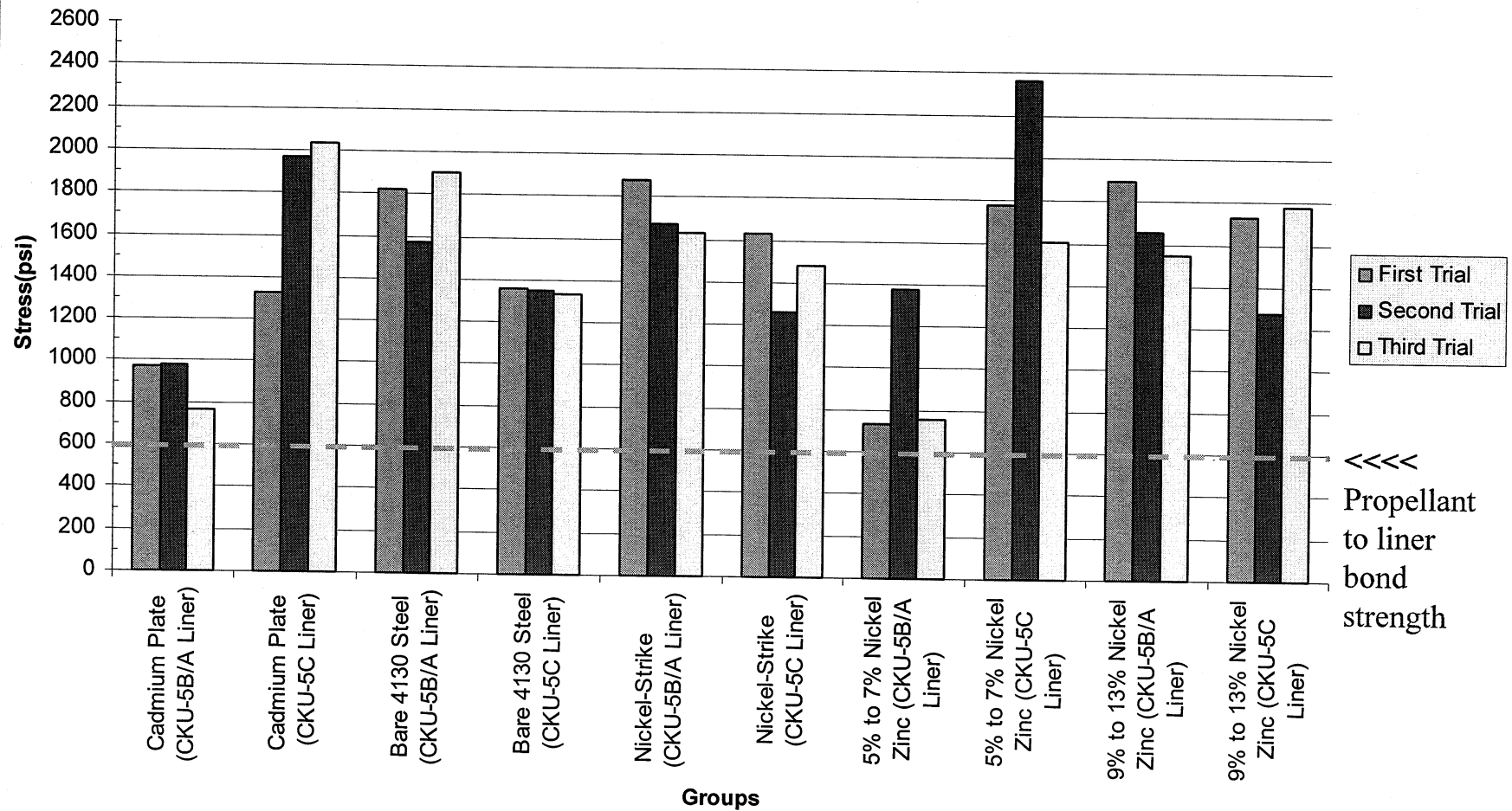
	Control	Cd Type II, CCC	Zn-12%Ni CCC	Zn-12%Ni PTFE	Zn-6%Ni
No Stress Relief	N/A	7% (5% max)	16% (5% max)	12% (5% max)	6% (5% max)
w/ Stress Relief	← No Breakage →				
No Stress Relief			w/ Stress Relief		

Liner Bond In Tension (BIT) Testing

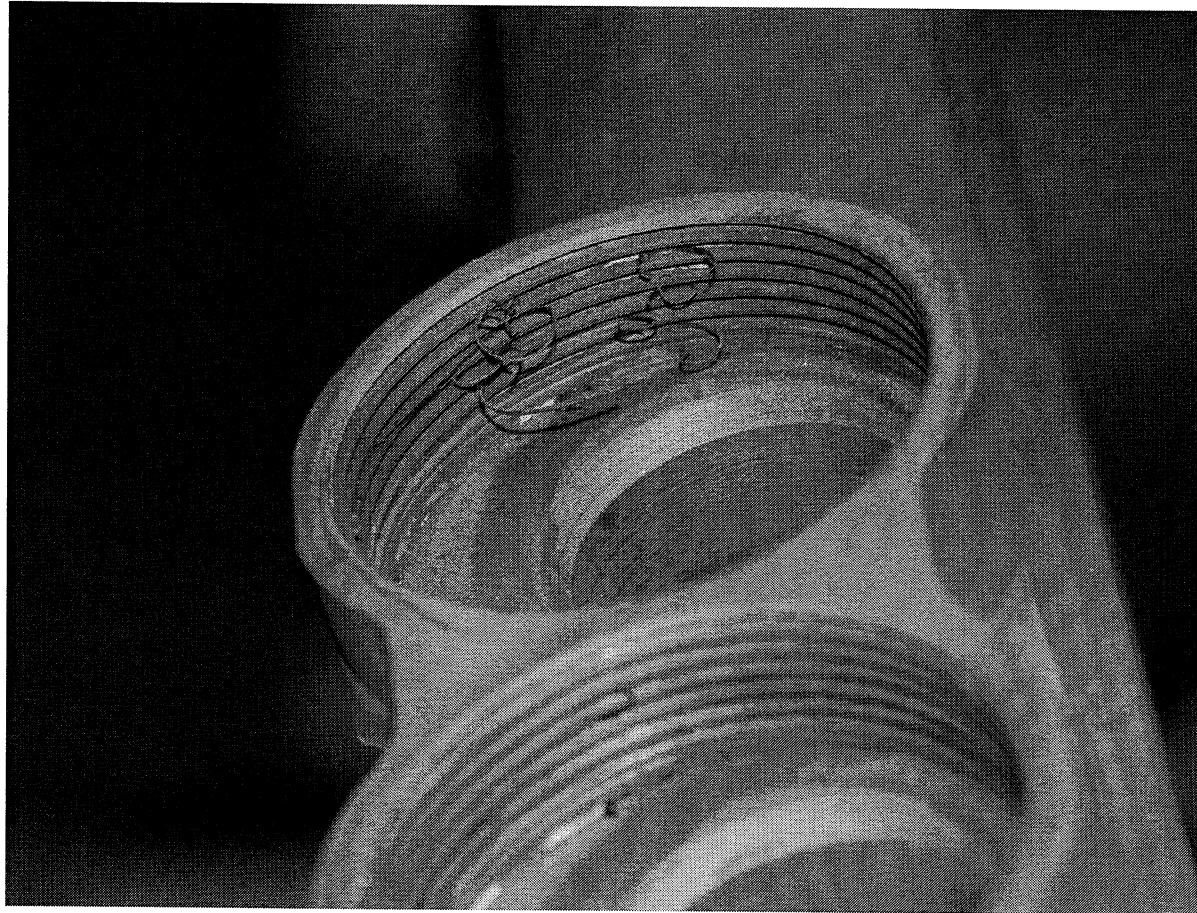
- 4340 Steel
- MK 109, MK 79
- CKU 5B/A
- MK 18/12
- CKU 5C/B
- 4340 Steel



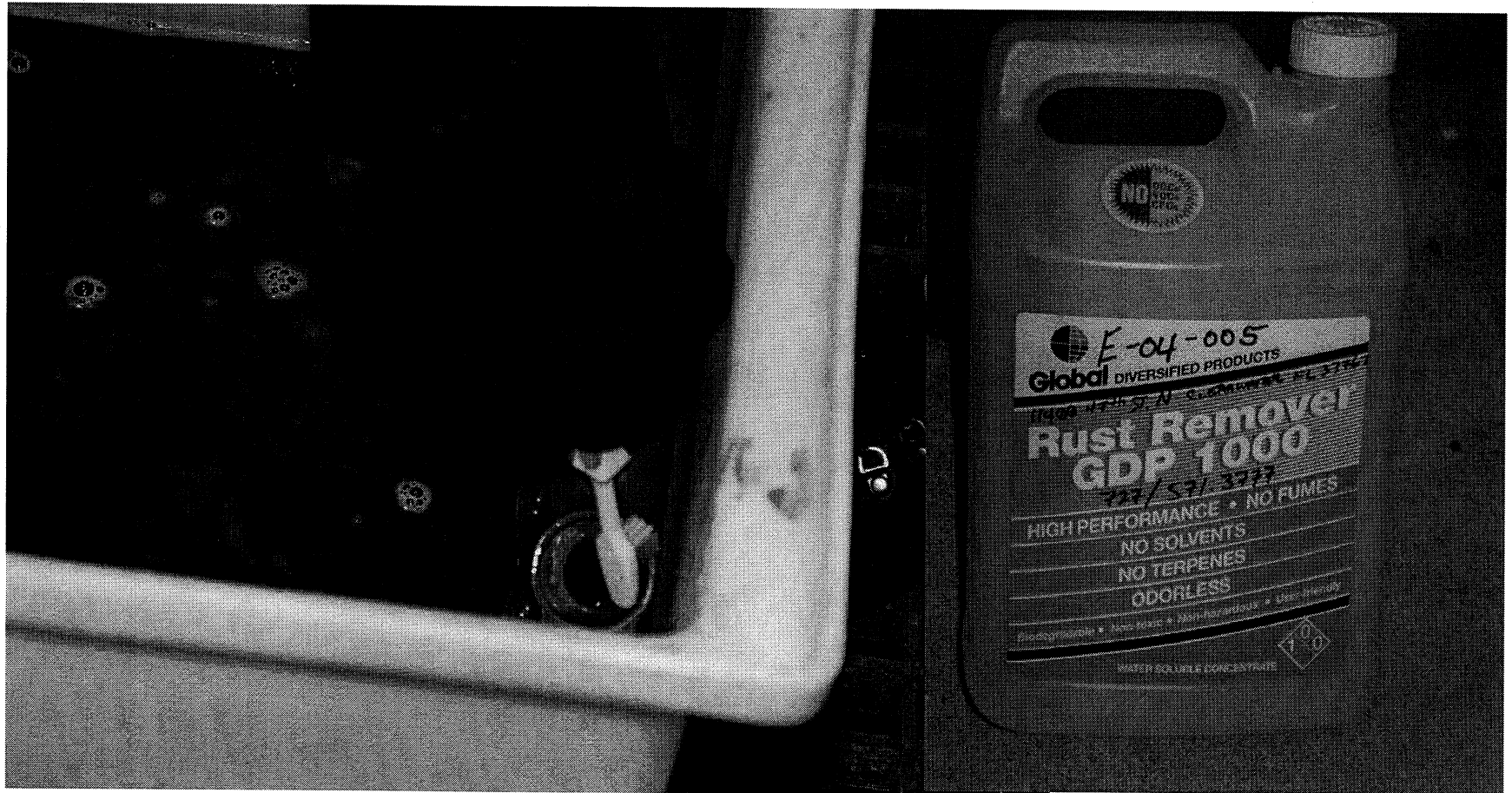
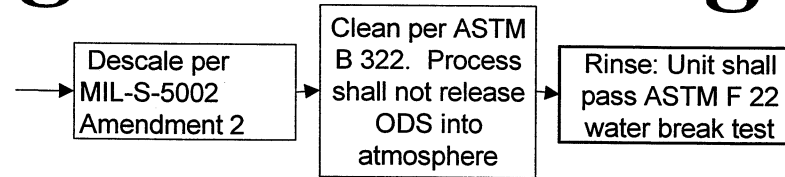
CKU 5C & 5B/A liner 4340 Steel BIT pull test: three (3) temperature cycles from 165°F to -65°F @ 7 hr. intervals



Descaling and Cleaning



Descaling and Cleaning

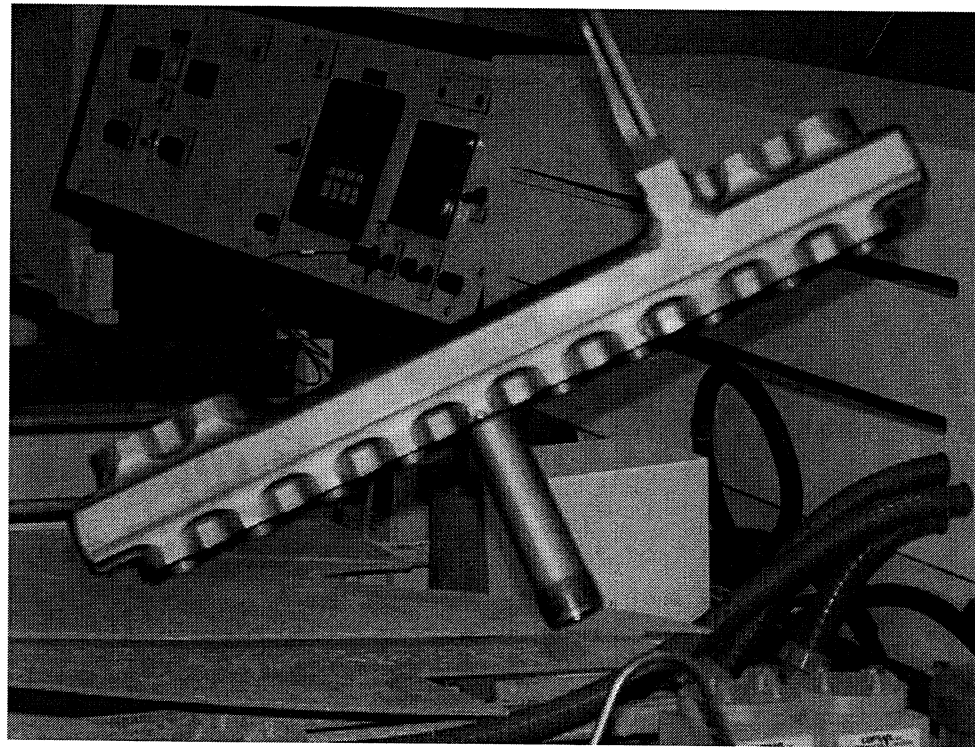


Nickel Strike

Activate surface to
receive nickel (i.e.,
HCL solution)

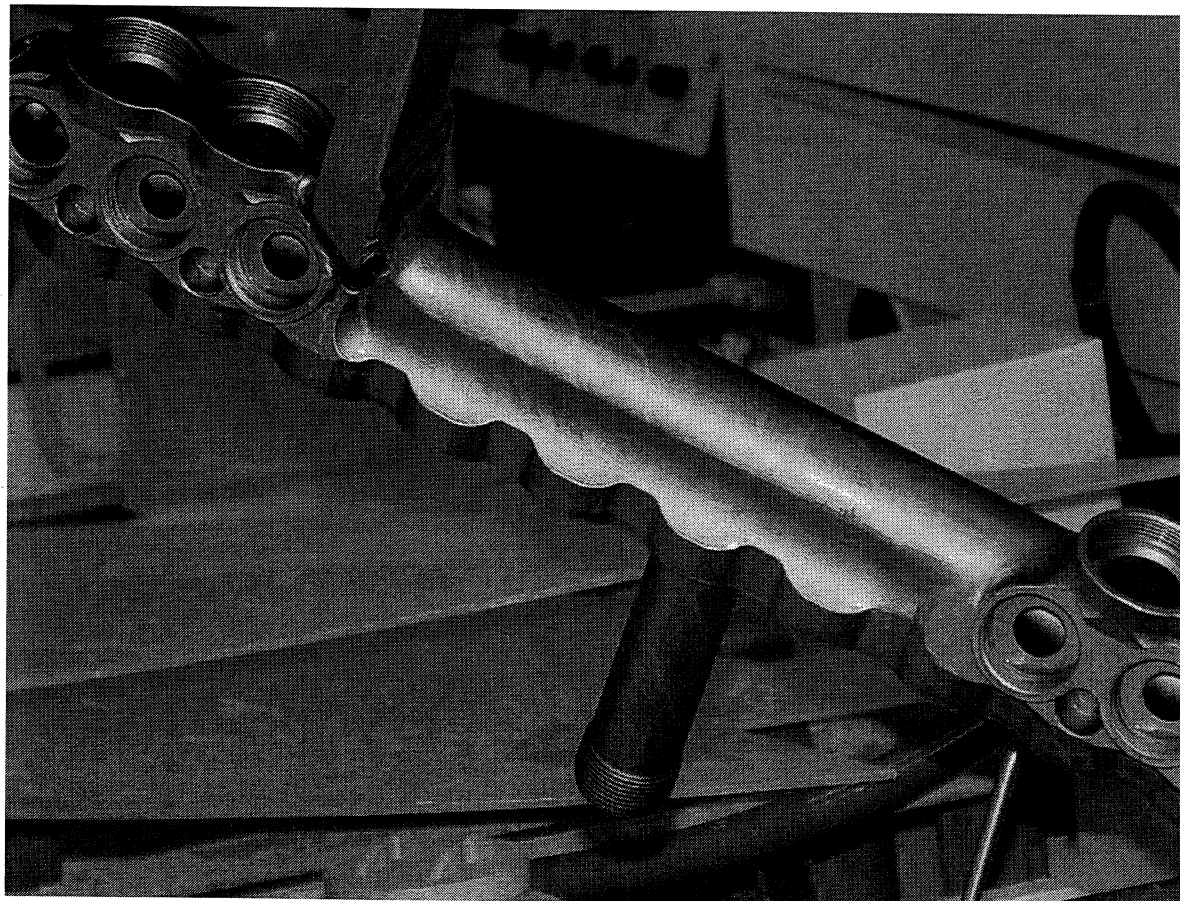
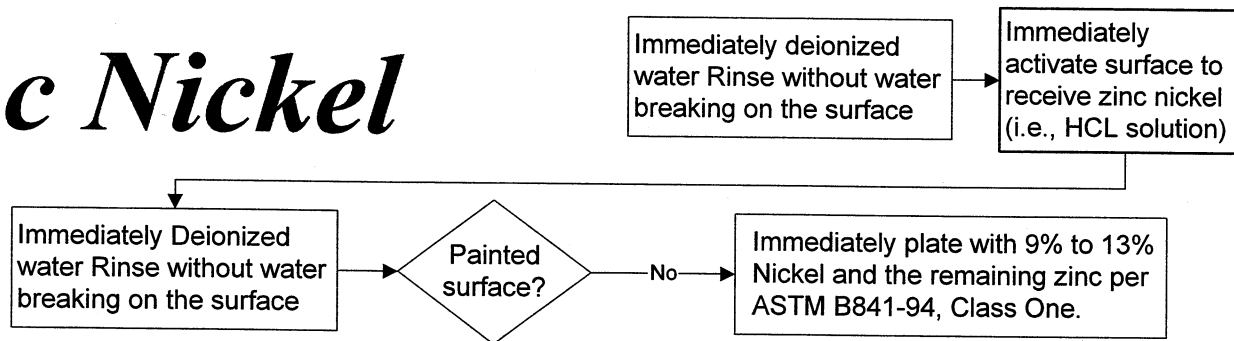
Immediately deionized
water rinse without water
breaking on the surface

Immediately apply .00005 to
.0001 Nickel-Phosphorus coating
per ASTM B733-97 Type V, Class
one on all surfaces.



- Minimize oxidation after activating metal surface
- Minimize oxidation of nickel strike surface

Zinc Nickel



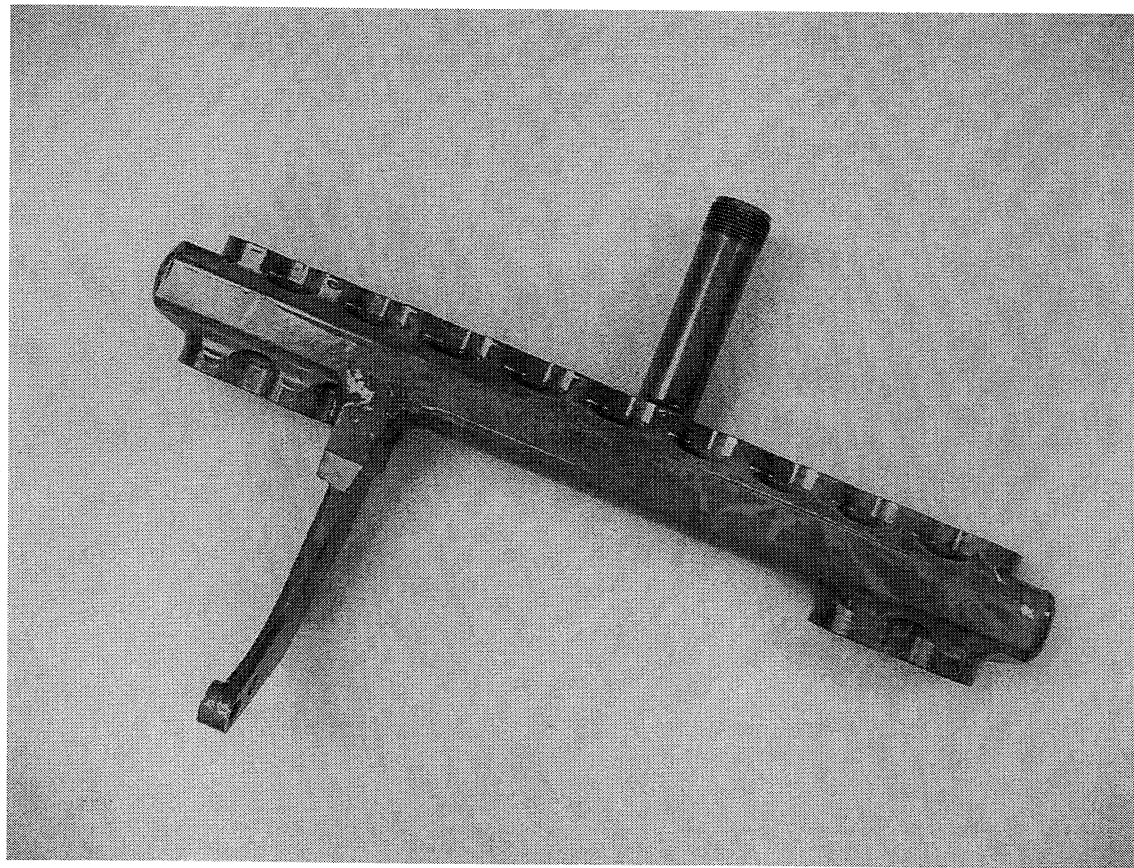
Trivalent Chromate Conversion Coating

Deionized
water Rinse

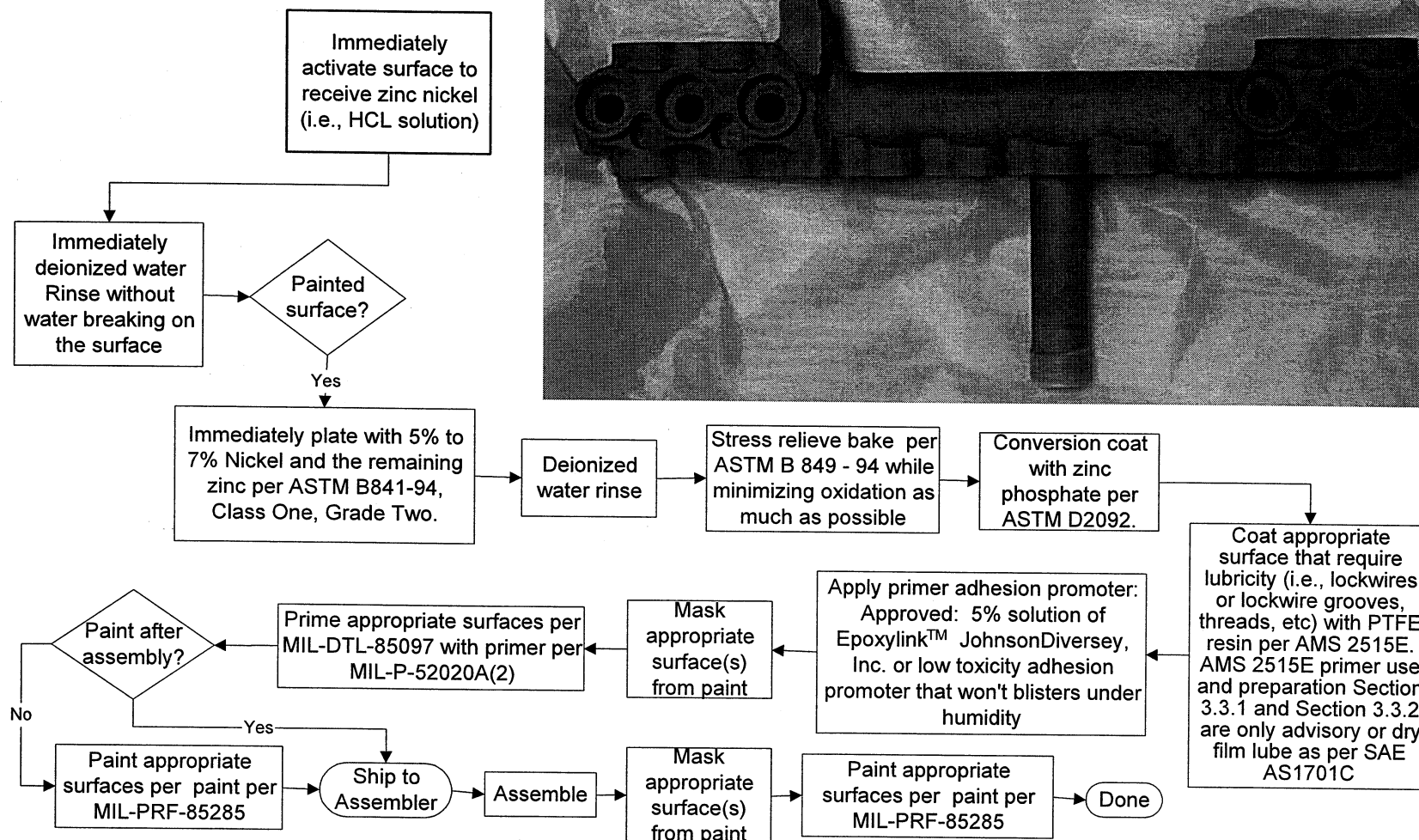
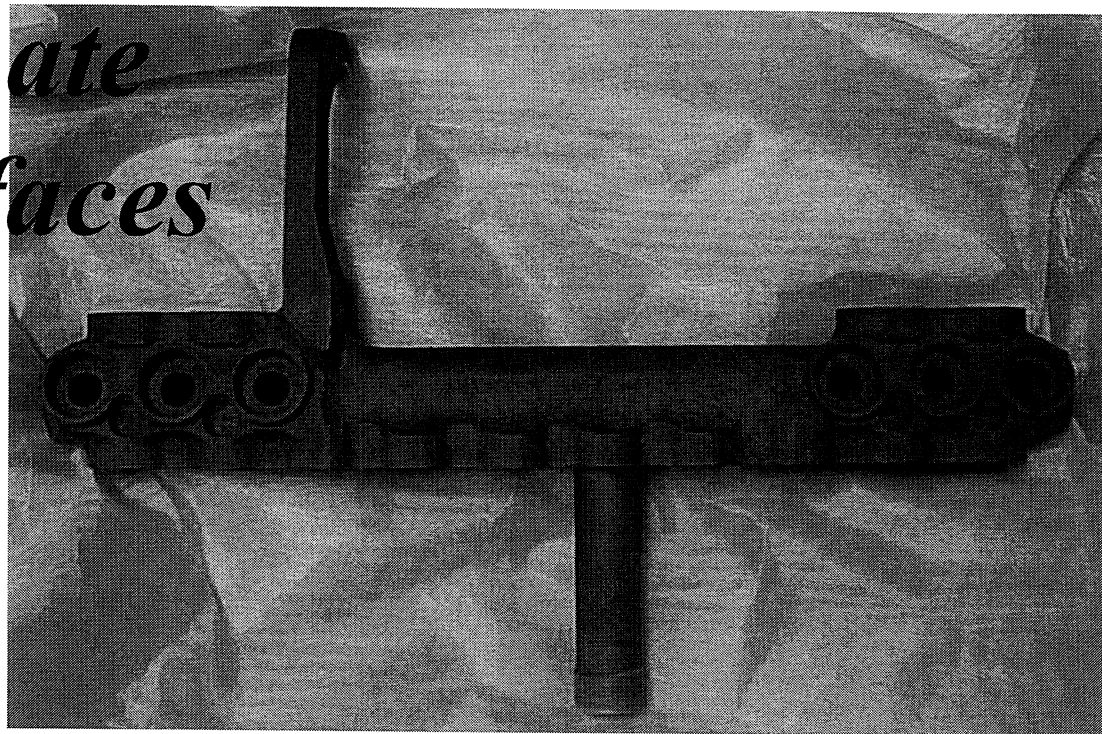
Stress Relieve Bake
per ASTM B 849 -
94 while minimizing
oxidation as much
as possible

Within three hours, conversion
coat with trivalent chromate
conversion coating (see navy
patent 6,527,841 / 6,663,700)

Done



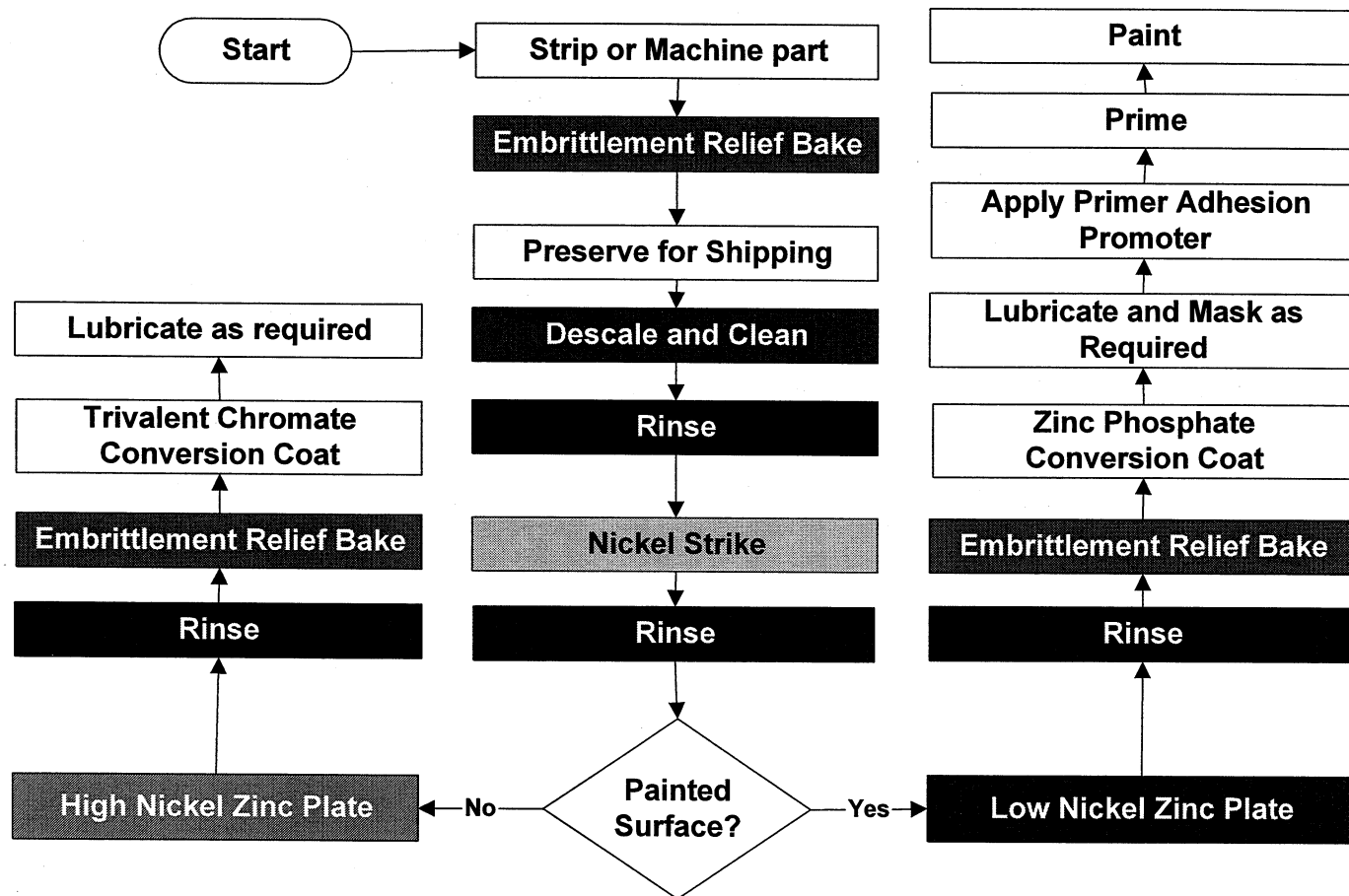
Zinc Phosphate Painted Surfaces



Paint Adhesion Promoter

- Must not contain hexavalent chrome.
- Must promote adhesion between zinc-phosphate and paint primer so that the paint won't blister under humidity.
 - JohnsonDiversey EpoxyLink® adhesion promoter has been qualified by the US army for use on gun barrels.
- Must not significantly reduce corrosion resistance of unprimed/unpainted part.

Zn-Ni Process Summary



Process Advantages

- Consistent part preparation
- Equivalent process for new or reworked parts
- Process different for painted parts

Test Underway

- Low toxicity paint adhesion promoter
- Quick primer application adhesion promoter
- Trivalent conversion coating salt fog testing

2nd Phase Testing Preliminary Results 65 Days Salt Fog



Threaded

Teflon® water based gel

Hex-Chromate Conversion

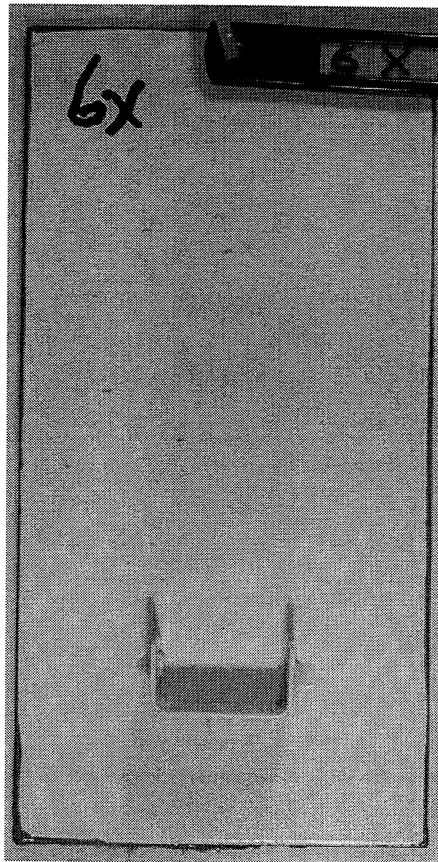
Zinc-12%Nickel

Nickel Strike

4130/ 4340 Steel

2nd Phase Preliminary Results

65 Days Salt Fog



Naval / Shipboard

Low VOC paint

Low VOC primer in 48 hrs

Phosphate Conversion

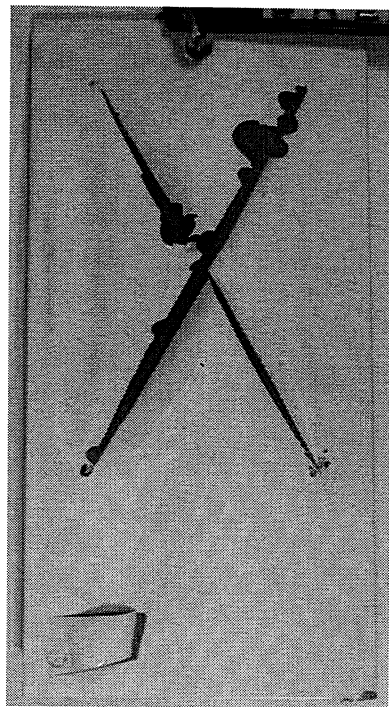
Zinc-5% Nickel

Nickel Strike

4130 Steel

2nd Phase Preliminary Results

65 Days Salt Fog



Painted

Low VOC paint

Low VOC primer

Tri-Chromate Conversion

Zinc – 5%-9% Nickel

Nickel Strike

4130 Steel

Lessons Learned

- Preparation.
 - Stress relieving before plating is vital to preventing hydrogen embrittlement.
 - Baking after zinc-nickel or cadmium plating is *not* effective in removing hydrogen embrittlement if there is no stress relieving before plating.
- Cleaning.
 - Stress relief oxide is effective in preventing corrosion during temporary storage.
 - Stress relief oxide is effectively removed using a low toxicity descaler.

Lessons Learned (Cont.)

- Nickel strike.
 - Exposure to oxygen must be minimized to assure good zinc-nickel adhesion.
- Conversion coating.
 - Trivalent chromate conversion coating is a viable low toxicity alternative to hexavalent chromate conversion coating.
- Primer adhesion.
 - A primer adhesion promoter or quick priming is vital to prevent blistering on a zinc phosphate conversion coat surface under high moisture.
 - Important to select an adhesion promoter that doesn't significantly reduce zinc phosphate's corrosion protection.

Conclusion

- Upon successful completion of this test program, we should have a qualified non-proprietary replacement surface coating system that doesn't induce hydrogen embrittlement for all of our PAD and most of our CAD items.

Acknowledgement

- John Goodwin, NSWC
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- Shawn Blough, CTC
- Jeff Adams, AMZ plating
- Crag Matzdorf, NAVAIR Patuxent river